PATENT
Atty. Docket No.: Q01-1044-US1
Client Matter No.: 85474.0011
Express Mail No. EL922181542US

DRIVER DEVICE AND METHOD FOR PURE TORQUE VOICE COIL MOTOR

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to the field of magnetic data read/write devices, and more particularly, to a device and method to control a voice coil motor in a disk drive with a circuit.

Discussion of the Related Art

In disk drives, a storage medium, such as a magnetic disk, is rotated. A spindle motor may cause the disk to rotate within the disk drive. The disk may be mounted to a spindle attached to the spindle motor. The spindle motor rotates the spindle and the disk to provide read/write access to the disk.

Disk drives may utilize a magnetic disk having concentric data tracks defined for storing data, a magnetic recording head, or transducer, for reading data from and/or writing data to the various data tracks, a slider for supporting the transducer in proximity to the data tracks in a flying mode above the storage media, a suspension assembly for supporting the slider and the transducer over the data tracks, and a positioning actuator coupled to the transducer/slider/suspension mechanism for moving the transducer across the media to the desired data track center line during a read or write operation. The transducer is attached to or is formed intregally with the

slider that supports the transducer above the data surface of the storage disk by a cushion of air, referred to as the air bearing, generated by the rotating disk.

The actuator positions the transducer over the correct track according to the data desired on a read operation or to the correct track for placement of the data during a write operation. The actuator is controlled to position the transducer over the desired data track by shifting the mechanism assembly across the surface of the disk in a direction generally transverse to the data tracks. The actuator may include a single positioner arm extending from a pivot point, or, alternatively, a plurality of positioner arms arranged in a comb-like fashion extending from a pivot point. A rotary voice coil motor ("VCM") is attached to the rear portion of the actuator assembly to power movement of the actuator over the disk.

The VCM is located at the rear portion of the actuator assembly and comprises a top plate spaced above a bottom plate with a magnet or pair of magnets therebetween. The VCM also may include an electrically conductive coil disposed within the rearward extension of the actuator assembly and between the top and bottom plates, while overlying the magnet in a plane parallel to the magnet. In operation, current passes through the coil and interacts with the magnetic field of the magnet so as to rotate the actuator assembly around its pivot to position the transducer as desired. The VCM may be a fast response, direct current ("DC") motor.

During operation of the disk drive, the actuator is driven by the VCM and positioned radially over the disk surface under the control of a positioning servo system. The VCM may be controlled by a microcontroller integrated into the disk drive components. The servo system is designed to accurately position the read/write transducer over a selected data track on

the disk in as short a time as possible. This action may be known as a seek operation. The servo system also may maintain the read/write transducer position over the data track as accurately as possible. This action may be known as a track following operation.

Performance of the disk drive may be increased or made more efficient by making the space between tracks smaller and by applying rapid forces in a short time. The access speed between tracks may also be increased. Motor resolution should be very fine to track data on the disk with a very tight tolerance. If able to follow the data track accurately, then one might be able to write tracks closer to increase disk drive capacity.

Actuator assemblies may have resonant frequencies that adversely affect the performance of the servo system. The resonances having the lowest frequencies limit the bandwidth of the servo system, which results in poor high frequency response and degraded disk drive performance. Because the mechanical assembly is not rigid, mechanical frequencies exist. When the head is in motion or sitting over a track, a moderate vibration may still affect positioning of the head. The VCM should account for these disturbances.

Attempts have been made to reduce the amount of disturbance in the actuator assembly. One attempt includes an additional motor that acts as a secondary actuator. Two motors may be used to correct the position of the head over the track. Disturbance may be reduced by letting the second actuator correct some of the vibration. Two motors, however, increase space requirements for the disk drive.

In addition, capacity of storage media is being pushed by different media and different recording techniques. One issue is attempting to retrieve a larger signal off of the disk by "flying lower," or closer to the surface of the

disk. When flying lower, the disk drive should be mindful of bumps, varnish and the like that may contact the head. When the head lands on the surface of the disk, it tends to stick which may damage the head. Further, every time the head touches the disk, the risk exists that the data under the head may be ruined.

Thus, attempts to increase capacity and speed in disk drives have resulted in a need for finer control over the mechanical assemblies of disk drives.

SUMMARY OF THE INVENTION

To achieve these and other advantages and in accordance with the purpose of the present invention, as embodied and broadly described, a driver device and method for a pure torque voice coil motor is disclosed.

Sub. A1

According to an embodiment of the present invention, a driver having a current control device for a voice coil moter in a disk drive. The driver includes a sensor to sense a coil current in the voice coil motor. The driver also includes a transconductance amplifier to detect an error current from the coil current and the command current. The driver also includes a compensator to integrate the error current into the coil current.

According to another embodiment of the present invention, a method for tracking a disk using a voice coil motor coupled to a driver is disclosed. The method includes sensing a coil current in the voice coil motor. The method also includes determining an error current from the coil current and a command current. The method also includes integrating the error current into the coil current.

According to another embodiment of the present invention, a current control device for a voice coil motor driver is disclosed. The voice coil motor

driver is coupled to a microprocessor to receive commands specifying a command current for a voice coil motor. The current control device includes an amplifier to drive the voice coil motor with a coil current. The current control device also includes a compensator circuit to integrate an error current with the command current to generate the coil current. The error current is detected with a sensor coupled between the amplifier and the voice coil motor.

According to an embodiment of the present invention, a driver having a current control device for a voice coil motor is disclosed. The driver includes an amplifier to drive the voice coil motor with a coil current. The coil current flows from one terminal of the voice coil motor to another terminal. Both terminals are coupled to the driver. The driver also includes a sensor to sense the coil current in the voice coil motor. The sensor is coupled between the amplifier and the voice coil motor. The driver also includes a current sense amplifier to amplify a voltage across the sensor. The voltage correlates to the coil current. The driver also includes a transconductance amplifier coupled to the current sense amplifier to receive the voltage and a command current. The transconductance amplifier calculates an error current. The driver also includes an integrator coupled to the transconductance amplifier to integrate the error current into the command current to determine the coil current.

According to another embodiment of the present invention, a driver having a current controller for a voice coil motor is disclosed. The driver includes a set of transistors coupled to the coil motor by a center tap. The set of transistors supply a coil current having a waveform to the center tap. The driver also includes a current sense amplifier to detect the coil current. The driver also includes a comparatar to shape a command current waveform to

the coil current wave form. The driver also includes a bipolar switch control to receive the command current waveform and to saturate the set of transistors.

According to another embodiments of the present invention, a method for controlling a voice coil motor accessing a track on a magnetic disk with a driver is disclosed. The method includes supplying a coil current to the voice coil motor. The method also includes amplifying the coil current. The method also includes shaping a command current waveform according to the coil current.

According to another embodiment of the present invention, a current control device within a driver for controlling a voice coil motor to seek a track on a storage media is disclosed. The current control device includes a coil current supplied to the voice coil motor along a center tap coupled to the driver. The current control device also includes a comparator to shape a waveform of a specified command current in accordance with a waveform of the coil current. The command current drives a bipolar switch coupled to the center tap.

According to another embodiment of the present invention, a driver having a current control device for controlling a voice coil motor during a seek mode. The driver includes a current sense amplifier to detect a coil current within the voice coil motor. The coil current is supplied by a center tap coupled to the driver and the voice coil motor. The driver also includes a current command to specify a command current having a waveform. The driver also includes a comparator coupled to the current sense amplifier to receive the current command and shape the command current waveform according to a waveform of the coil current. The driver also includes a bipolar

switch coupled to the comparator to turn on and off a set of transistors to supply the command current to the center tap.

According to another embodiment of the present invention, a driver for controlling a voice coil motor during a retract mode is disclosed. The voice coil motor has a first coil motor and a second coil motor. The driver includes a sensor to sense a velocity voltage across the second coil motor. The driver also includes an error amplifier to calculate a differential between the velocity voltage and a command voltage. The driver also includes a retract amplifier to compensate the command voltage with the differential.

According to another embodiment of the present invention, a method for controlling a voice coil motor having a first coil motor and a second coil motor with a driver during a retract mode is disclosed. The method includes detecting a velocity voltage with the second coil motor. The method also includes determining a differential voltage between the velocity voltage and a command voltage. The method also includes compensating the command voltage with the differential voltage.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are intended to provide further explanation of the invention as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are included to provide further understanding of the invention and are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and together with the description serve to explain the principles of the invention. In the drawings:

FIG. 1 illustrates a disk drive with a voice coil motor in accordance with an embodiment of the present invention;

FIG. 2 illustrates a pure torque voice coil motor driver configured to a track following mode in accordance with an embodiment of the present invention;

FIG. 3 illustrates a pure torque voice coil motor driver configured to a seek mode in accordance with an embodiment of the present invention; and

FIG. 4 illustrates a pure torque voice coil motor configured to a ramp load mode in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Reference will now be made in detail to the preferred embodiments of the present invention, examples of which are illustrated in the accompanying drawings. A motor driver and ramp loading circuit is disclosed for a VCM. The VCM has two coils, or coil motors, that allow dual modes of operation. During access, the two coil motors are driven with the same polarity to generate the access torque. During tracking, the two coil motors are driven with opposite polarity forming a force couple. The force couple produces the desired amount of torque needed to follow a track while eliminating the reaction forces on the motor bearing. By eliminating the reaction forces on the bearing, a reduction in both bearing wear and run out is achieved. The improved tracking due to bearing run out reduction would lead to an increase in the disk file storage capacity.

Embodiments of the present invention include a motor driver having three modes of operation. First is a switch mode peak current controller for access operations. Second is a linear mode class AB amplifier current

controller for track following. Third is a linear mode velocity controller for ramp load.

During access, the switch mode controller allows shaping of the motor current waveform without an increase in the power consumption. A reduction in the seek acoustic may be achieved by shaping the access current waveform. During ramp load the motor driver may utilize one of the VCM coils as a velocity transducer while using the other coil to provide the needed torque to regulate the VCM velocity in a continuous manner.

Fig. 1 depicts a disk drive 10 with a voice coil motor in accordance with an embodiment of the present invention. Disk drive 10 may be a magnetic hard disk drive. Disk drive 10 reads and writes data to the storage media 28. Storage media 28 may be magnetic storage media that is mounted on spindle 29 and rotated by spindle motor 27. Actuator 18 moves read/write heads 30 across storage media 28 in response to commands from a host. VCM 20 comprises voice coils 26 and provides the force necessary to move actuator 18. VCM 20 employs voice coils 26 that varies a magnetic field in the proximity of a permanent magnet 32. The magnetic field varies by changing the current within VCM coils 26.

Microprocessor 12 implements a servo controller program by executing an estimator 38 control loop program. This action control the current to VCM 20 through digital-to-analog converter 22 and current driver 36. Current driver 36 provides current to VCM 20 through line 35. Microprocessor 12 receives servo position information read by head 30 from media 28. The position information is amplified by pre-amplifier 31 and demodulated by servo channel 25.

VCM 20 may be a pure torque voice coil motor. Torque is created due to motion of the arm and due to mechanical disturbances. A way to reduce torque is to implement a pure torque motor around the center of gravity of the moving mass. The disturbance forces are balanced. The principle behind the pure torque VCM is not to waste any moment, and try to utilize all the torque. All electrical energy put into the coil winding to move the motor is going to change into torque for the desired motion.

In a preferred embodiment, a stacked coil, pure torque motor is implemented. The stacked coil embodiment uses an additional coil, or two coils over each other. When the current is driven in the coil in the same direction, an axis torque is generated. When the current is driven in the opposite direction, a force couple is generated that is balanced around the bearing of the assembly mass.

Another approach may be shaving the magnetic circuit and using a permanent magnetic/stationary part of the motor as the coil is moving. An additional coil, however, should be less costly than an additional magnet.

Sub. A3

Fig. 2 depicts a pure torque voice coil motor driver configured to a track following mode in accordance with an embodiment of the present invention. Track following mode indicates that the mechanical assembly is moving the head to follow a track. A force couple should be created, as disclosed above. Actuator assembly 200 includes VCM 204. Driver 202 provides current and control for VCM 204. Driver 202 may receive commands from a microprocessor and current commands from a DAC to place VCM 204 into different modes or to perform various operations. Driver 202 may be integrated in the power integrated drip ("IC") that is located on the drive PCB.

VCM 204 may comprise two separate motors, coil motor 206 and coil motor 210. Coil motors 206 and 210 also may be known as coils. Coil motors 206 and 210 comprise coil windings that receive a current to create a magnetic field. Coil motors 206 and 210 are connected to a center tap 208. Thus, instead of four terminals from VCM 204 for two different coil motors, three terminals are used to create the force couple according to the present invention. By connecting the coils of coil motors 206 and 210 in this manner, each coil will induce a magnetic field in the opposite direction of the other coil.

If two coils are connected in series, and not with the center tap, and current is driven from one terminal to the other terminal, then a force couple may be created. For example, if current is driven from the terminal for coil motor 206 to the terminal for coil motor 210, then VCM 204 may create a force couple. The force couple may be a certain percentage of the available torque, but would eliminate the reaction forces on the mechanical assembly of VCM 204. Therefore, in track following mode, driver 202 may see only one coil with center tap 208 disconnected.

Center tap 208 may be driven by two DMOS transistors 220 and 222. With center tap 208 disconnected, the gates of transistors 220 and 222 are connected to ground. Transistors 220 and 222 are turned off, or "floating."

Driver 202 includes amplifiers 216 and 218 in a known AB amplifier configuration. Amplifiers 216 and 218 may deliver the current to drive VCM 204. Amplifiers 216 and 218 receive current from error buffer amplifier 233. The amount of current may be determined by a VCM current command 230. Current command 230 may be generated by a microcontroller coupled to driver 202. Current command 230 is received at error buffer amplifier 233,

which then indicates to amplifiers 216 and 218 the amount of current to drive VCM 204.

~~Driver 202 may desire to know whether the current through VCM 204 is at or about the current specified by current command 230 from the DAC programming. The claimed embodiments of the present invention detect the current within VCM 204 and controls the current from amplifiers 216 and 218 to approximate the current defined by current command 230. Integrator 224 and transconductance amplifier 232 detect an error current within VCM 204 and integrate the error current into the command current.~~

Referring back to VCM 204, a coil current may be sensed through the coil windings by sensor 212. Preferably, sensor 212 is a resistor. More preferably, sensor 212 is a resistor having low resistance. Sensor 212 may be external to driver 202. The current across sensor 212 creates a sense voltage between VCMA and SENAL in Fig. 2. Current sense amplifier 232 detects the sense voltage. Accordingly, VCMA may be sense amplifier HI and SENAL may be sense amplifier LO.

Current sense amplifier 232 amplifies the sense voltage to be fed into transconductance amplifier 226. Transconductance amplifier 226 amplifies and converts from voltage to current the difference between the VCM current command 230 voltage and the amplified current sense voltage. The error current from tranconductance amplifier is fed into a dynamic compensator network 224. Compensator 224 includes a capacitor and a resistor. The capacitor serves as an integrator for the error current. By adding integration, the current control loop gain is increased and the loop steady state error may be eliminated. A phase lead term may be produced by adding a resistor in series to the capacitor. The phase lead term is designed to cancel the phase lag introduced by a motor electrical time constant. The

current control loop bandwidth may be increased by compensating for the phase lag introduced by the motor electrical time constant. Thus, an improved loop transient response may result and better tracking in track following mode may be enabled by the increased loop bandwidth.

The control of the current is driven by the sensed current through sensor 212. Sensor 214 also may be included in the sensing circuit. Preferably, the current in the windings of VCM 204 should be about equal with the current specified by command 230. The current control loop bandwidth should be high enough to meet the transient response of the driver system. For example, the loop should be anywhere from about 20 kHz to 30 kHz of bandwidth.

~~By adding integrator 224 after the error current is determined, the potential for DC error is reduced. Integrator 224 includes a resistor in series with the capacitor. A time constant may be built with integrator 224, causing a time phase lag.~~

Thus, embodiments of the claimed invention disclose building a transconductance current control for VCM 204. The error current is determined and integrated into the command current. The integrated current drives amplifiers 216 and 218 to deliver the winding current.

The overall current control loop may be referenced to an internally generated reference voltage. Current sense amplifier 232, transconductance error amplifier 226 and error buffer amplifier 233 operate in a bipolar fashion around the internally genrated reference voltage. Amplifier 234 is used to generate the driver voltage reference. In order to drive the VCM winding diferentially in a symmetrical fashion, the output voltage drive has to be level shifted to half of the supply voltage VISOV/2. The amplifier 236 is used to

generate VISOV/2 for the output amplifier. Symmetrical drive around VISOV/2 may be important during the access mode where the HDD seek performance is insensitive to the seek direction.

Class AB output amplifiers 216 and 218 are biased by the VISOV voltage. The VISOV voltage is connected to the spindle motor driver bridge. During normal operation, the VISOV voltage is connect to the disk drive power supply VCC via switch 238. When power is absent, switch 238 is opened and VCM driver 202 uses the voltage generated by the spindle rectified BEMF as its power supply to perform retract and ramp load.

Fig. 3 depicts a pure torque voice coil motor driver configured to a seek mode in accordance with an embodiment of the present invention. Seek mode indicates that the mechanical assembly is moving the head to find, or seek, a track. The two coils of VCM 204 are driven in parallel. Actuator assembly 200 includes driver 202 and VCM 204. Driver 202 provides current and control for VCM 204. Driver 202 may receive commands from a DAC to place VCM 204 into different modes or to perform various operations.

In linear motor driver technology, the temperature rise in the motor driver integrated chip may be due to increased power dissipation. This dissipation, in turn, prohibits the shaping of the motor current waveform that flows through the coils. Operations to shape the motor current waveform eliminates the acoustic noise produced by the disk drive while in seek mode. In modern disk drive applications, an increasing need for reducing the amount of acoustic noise is desired during seek operations. Embodiments of the present invention may allow shaping of the motor current without an increase in the power dissipation in the motor driver integrated chip.

In seek mode, the AB amplifiers 216 and 218 of Fig. 1 are disabled. The gates of DMOS transistors 220 and 222 are controlled by logic elements of driver 202 to provide current to VCM 204. Transistors 220 and 222 may be known as "bore" transistors. Driver 202 delivers the current to center tap 208. By receiving the current from center tap 208, coil motors 206 and 210 are driven in parallel.

For switching operations, driver 202 is turned on for a certain duty cycle with driver 202 controlling the actuator in one direction to achieve the current received by the DAC programming, or the command current 230. Once achieved, the driver is switched to off. Under this operation, driver 202 may be known as a peak current, switch driver. Current in the coils would equal the command current at their peaks.

According to embodiments of the present invention, driver 202 may be turned on for a saturation period depending on the current valve from DAC 230, and then turned off for a constant period of time. Driver 202 turns on the appropriate transistors depending on the polarity of the commanded current from DAC 230. The output voltage of motor current sense amplifier 232 is about equal to the sum of current in both coils motors 206 and 210. When comparator device 302 detects that the motor winding current sum has reached the commanded current, driver 202 is switched off. The current in each winding rises to about half of the command current. The "off" period may be programmable by a microprocessor and may determine the switch mode operation duty cycle. Thus, driver 202 in seek mode may be known as a constant off time peak current controller.

For example, DMOS transistor 220 is saturated to control VCM 204 into a certain direction. The driver current flows from driver 202 to center tap 208. When the driver current reaches about one half the amount

specified by current command 230, then transistor 220 switches off. Driver 202 keeps transistors 220 and 222 off for a certain period of time. When the period is finished, transistor 220 is saturated again to get the driver current flowing back through center tap 208.

Full saturation in turning on and off the transistors may improve the efficiency of driver 202. Further, the power consumption in driver 202 may be reduced. The power transistor saturates during the "on" phase, thereby reducing the power dissipated in the power IC to drive the motor windings. Thus, efficiency may be improved and power consumption reduced. Using this technique during seek mode may allow driver 202 to use any waveform shape of current to drive VCM 204. During seek mode, if a linear current drive is used, the shaping of the commanded current may increase the power dissipated in the power IC. A temperature rise of the power IC package due to the increase in the power dissipation may prohibit current waveform shaping. Thus, switch mode control for driver 202 may be desired.

According to embodiments of the present invention, current sense amplifier 232 may provide a sum of the two currents flowing in coil motors 206 and 210. The sum may be about equal to the drive current flowing through center tap 208. Using current sense amplifier 232, driver 202 may avoid using independent current switch power control loops. The sum of the motor currents may give the torque created by VCM 204 because coil motor 206 and coil motor 210 are being driven in the same direction. Driver 202 should be an accurate torque driver for the two coil motors 206 and 210. Thus, driver 202 may avoid running the coil motors 206 and 210 on two different loads. Preferably, driver 202 is configured to be a bipolar peak current driver, or control, for a switch mode.

Referring to Fig. 3, current sense amplifier 232 detects the coil current flowing through coil motors 206 and 210. The coil current may be the same as the driver current flowing through center tap 208. Current sense amplifier 232 may amplify the coil current. Comparator device 302 receives the output from current sense amplifier 232 and a command current specified by current command 230. Comparator device 302 detects when the output voltage of current sense amplifier 232 reaches the VCM current command of DAC 230 and then turns off driver 202. Driver 202 stays off for the period specified by Toff programming, and then turned back on. The process may repeat itself.

Comparator 304 determines the polarity of the commanded current and programs predriver logic 310 and 312 to turn on the appropriate transistors. If the commanded current is greater than VREF, then both of the high side transistors 306 and 308 are turned on. The low side center tap driver transistor 222 may be controlled by the constant Toff chapper while the high side center tap driver transistor 220 is off. During the driver cycle, the winding A current comes from the power supply via high side transistor 306, passes through winding A, then passes through transistor 222 to ground while the winding B current comes from the power supply via high side transistor 308, passes through winding B, then passes through transistor 222 ground.

Thus, any shape for the waveform of the command current may be used to drive VCM 204 without increasing power consumption within driver 202. Further, reduction in acoustic forces within the disk drive may be achieved by shaping the command current waveform.

Fig. 4 depicts a pure torque voice coil motor driver configured to a ramp load, or retract, mode in accordance with an embodiment of the present

invention. Storage media heads may use ramp loading technology to achieve the forecasted capacity growth of the disk drive. Known ramp loading schemes suffer from the absence of an accurate velocity transducer to control the ramp load and unload velocity. The velocity tolerance of the ramp loading may effect the reliability of the disk drive. Schemes may use continuous feedback of the velocity by sampling the back electro-magnetic force to provide an acceptable tolerance, but require a complex switch mode operation of the ramp load controller, or driver. Switch mode operation, however, may create undesirable acoustic noise during ramp load.

Embodiments of the present invention may use the second coil motor as a velocity transducer to provide a continuous velocity feedback to driver 202. The motor driver ramp loading circuit is a closed loop linear velocity regulator. The regulator uses a first coil motor to control the motion while the second coil motor is used to sense the velocity. Embodiments of the present invention should provide the needed precision of the ramp load and unload velocity.

Ramp load schemes attempt to park the head when the disk is not rotating. The head may be lifted and parked. Power may be detected as decreasing, and the actuator is moved with the head to unload the head from the disk. When the disk is rotating again, driver 202 may load the head back onto the disk. In performing ramp load operations, disk drives should be careful not to hit the ramp too fast. Wear and tear on mechanical components may occur, and reduce the lifetime of the disk drive.

Referring to Fig. 4, the coil within second coil motor 210 may be used as a velocity transducer along with a sensor 420 to sense the velocity of VCM 204. Once in track mode, VCM 204 may be tri-stated. Thus, coil motor 206

may be used to control the motion of the head, while coil motor 210 may be used to sense the velocity.

Coil motor 210 produces a voltage across VSENBL and VCMCT. Sensor 420 may be a resistor that senses the voltage across the terminals. Differential amplifier 232 detects the voltage and produces an output to error amplifier 226. Differential amplifier 232 may be the same logic element as current sense amplifier 232, but is referred to differently because of the difference in functionality with regard to the ramp load mode. Error amplifier 226 may be the same logic element as transconductance amplifier 226, but is referred to differently because of the difference in functionality with regard to the ramp load mode. The output of differential amplifier 232 may be proportional to the velocity of VCM 204, as sensed by coil motor 210 and sensor 420.

Error amplifier 226 calculates the error, or the difference, between the measured velocity and a command velocity 402 from the DAC programming. Error buffer amplifier 233 amplifies the error and provides the error to retract amplifier 406. The retract linear velocity control loop may be compensated dynamically with the resistor and capacitor compensation network 224. Compensation network 224 may include the same elements as the track following transconductance loop compensation network of Fig. 2. Retract amplifier 406 drives coil motor 204 to increase or reduce velocity, and to set motor velocity to the programmed velocity specified in velocity command 402. Transistors 220 and 222 may deliver the current to drive coil 206, as disclosed above. Therefore, driver 202 may configure itself to be a retract velocity regulator control loop when in ramp load, or retract, mode.

Embodiments of the present invention may provide a continuous analog loop to perform constant velocity retract, or to control velocity ramp

load or retract. With a continuous analog loop, embodiments may design the loop with a much wider bandwidth without perceivable steady-state error. Switch mode techniques no longer may be needed. Noise and complicated circuitry to implement the switch mode may be reduced, which, in turn, reduces costs to driver 202. Thus, a more precise controller with increased bandwidth may be used to perform ramp load.

During power on, ramp load and unload operations, the VCM curent command of DAC 230 may be used as the VCM velocity command of DAC 402. During power off, a retract velocity reference 404 is used to set the desired velocity for unloading the heads. If power is lost during a VCM seek towards the ramp, a power down retract sequencer logic 412 may be used to brake the VCM 204 using both motor coils before engaging the linear velocity controller.

It will be apparent to those skilled in the art that various modifications and variations can be made in a probe head of the present invention without departing from the spirit or scope of the invention. Thus, it is intended that the present invention covers the modifications and variations of this invention provided that they come within the scope of any claims and their equivalents.